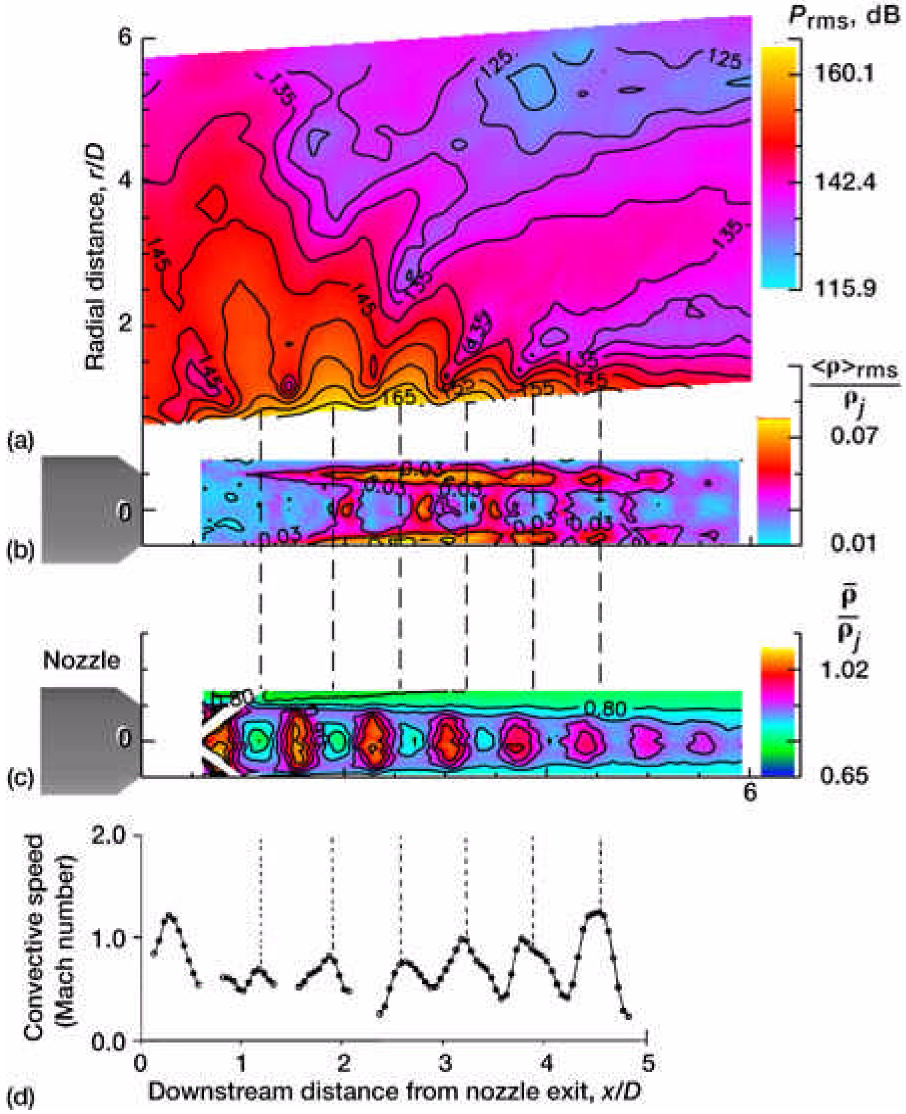
Screech Noise Generation From Supersonic Underexpanded Jets Investigated

Many supersonic military aircraft and some of the modern civilian aircraft (such as the Boeing 777) produce shock-associated noise. This noise is generated from the jet engine plume when the engine nozzle is operated beyond the subsonic operation limit to gain additional thrust. At these underexpanded conditions, a series of shock waves appear in the plume. The turbulent vortices present in the jet interact with the shock waves and produce the additional shock-associated noise. Screech belongs to this noise category, where sound is generated in single or multiple pure tones. The high dynamic load associated with screech can damage the tailplane.

One purpose of this study at the NASA Glenn Research Center at Lewis Field was to provide an accurate data base for validating various computational fluid dynamics (CFD) codes. These codes will be used to predict the frequency and amplitude of screech tones. A second purpose was to advance the fundamental physical understanding of how shock-turbulence interactions generate sound. Previously, experiments on shock-turbulence interaction were impossible to perform because no suitable technique was available. As one part of this program, an optical Rayleigh-scattering measurement technique was devised to overcome this difficulty.



Mechanism for screech noise generation from a 2.39 nozzle pressure ratio (Mach 1.19) supersonic jet produced from a circular choked nozzle. (a) Root-mean-square noise pressure fluctuation. (b) Normalized air density fluctuation. (c) Normalized, time-averaged air density. (d) Convective speed of turbulent vortices.

Rayleigh-scattering measurements provided the flow information for this figure (parts (b), (c), and (d)), and the acoustic information (part (a)) is from a microphone. Since screech appeared as a single tone for the 2.39 nozzle pressure ratio (Mach 1.19) jet, a phase-averaging process was employed for data acquisition. The time-averaged air density plot (part (c)) shows the periodic shock waves present in the plume. The red-yellow regions have higher densities from shock compression, and the blue-green regions correspond to the lower density in the expansion regions. Part (b) shows the strength of turbulence fluctuation as measured through root-mean-square density fluctuations. Once again, the red-yellow zones represent high fluctuation. Note that the turbulent fluctuations are modulated as they pass over the periodic shock train. Part (d) shows the speed variation of the turbulent vortices. The actual speed is divided by the speed of the ambient sound to arrive at the convective Mach number values. Clearly, the vortices go through a periodic acceleration and deceleration. Part (a) shows the sound pressure fluctuation measured in the jet vicinity. Close to the jet boundary, the yellow to orange pattern (bottom left of part (a)) shows a series of peaks and valleys from which the rest of the sound field appears to radiate. The peaks are identified as the sound sources. Finally, the vertical chain lines link all the parts. The sound sources are located in the regions of the jet where the turbulent vortices are fastest and have the strongest fluctuations. Further analyses showed that the spacing between the sound sources follows an interference scale that is somewhat different from the shock spacing. This length scale was used to develop an exact screech frequency formulation (refs. 1 and 2).

Find out more about this research http://www.grc.nasa.gov/WWW/jp/

References

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